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NUCLEAR PHYSICS

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To understand the subject material for the work in Nuclear Physics of today it would be well to glance briefly toward an ancient science which was largely abandoned a century ago and classed by the reputable sciences of the times with astrology and mysticism. This science was known as alchemy. The Greeks in the early centuries of the Christian era were among the first to consider seriously the possobilities of changing the baser metals into the precious ones, silver and gold. And though their efforts failed, the idea was a fascinating one and through the centuries that followed kept cropping up, stimulated by the need for ornaments or the sinews of war. Though the quest was never successful, it did lead to many useful discoveries such as possible alloys and compounds useful as medicines and dyes. It is said that belief in the successful transmutation of the chemical elements was held well into the 17th century being advocated by the ablest men of that time—Newton, Leibnitz, and Boyle.

Perhaps one of the last serious efforts to account for all the chemical elements and their compounds in terms of common basic material was due to Prout. Along with many other of the scientists of his time Prout (1785-1850) was a physician and was interested in alchemy as a phase of chemistry rather than in chemistry as a sort of by product of alchemy. He was led to conclude from experiments on the relationship of the specific gravity of gases to the weights of their atoms that hydrogen was the fundamental stuff. His hypothesis acted as a stimulant to chemical research. Atomic weights were more accurately determined and as is readily seen by glancing at a periodic table the hypothesis was shown to be so apparently false that it was entirely abandoned. feeble attempts to revive it by inventing half atoms seeming entirely ridiculous in light of accumulating evidence on fractional values in atomic weights. Hydrogen was even abandoned as a base for comparing atomic weights and oxygen (at 16) was chosen instead. Research in alchemy was definitely outlawed from the scientific.

In the closing years of the 19th century x-rays were discovered and in the search for methods of producing and detecting these rays, Becquerel in 1896 found that certain compounds containing uranium, the most massive of the chemical elements, apparently emitted rays similar in their effect on photographic plates to x-rays. This discovery led directly to the discovery and study of the whole series of radioactive elements in early years of our present century. The names of Curie, Rutherford, J. J. Thompson figuring prominentiy in literature on the subject.

There will be no attempt made here to present the detail of the radioactive elements and their interrelations. There

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Credit to Whom Credit is Due

We wish to express our appreciation to our advertisers who have consistently supported this Journal and the work of our State Chemistry Association.

In all fairness we must recognize the fact that they have made it possible for the Association to publish the worth while material presented before it and to serve better the interests of the chemistry teachers of the State of Illinois and adjoining States. Certainly these business firms deserve our consideration when we buy or requisition the supplies, equipment, books, etc., needed during the year.

We note that the following companies have taken advertising space during the past year and you will recall that some of them have consistently advertised in each issue since this Journal was first published.

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ANNUAL SPRING MEETING

A most promising meeting is in store for chemistry teachers at Macomb, Illinois, March 28. Professor Howard W. Adams of Normal University, president of our association, has arranged a very timely symposium on the problem of laboratory vs. the demonstration method of teaching chemistry. For a time there was a growing belief among teachers that the demonstration method was somewhat superior to the laboratory method. However, more recently the laboratory method has been gaining support.

We must remember that other factors than efficiency of teaching have favored the demonstration method. Administrators have been urging it as a matter of economy. The change from the double laboratory period to the hour system has caused many teachers to adopt the demonstration method to an increasing extent.

Since this problem is a special one for the high school teacher it seems especially desirable to have it discussed from the different viewpoints by capable men in this field. The college men present will of course take part in the general discussion.

Other interesting features of the day's program are the demonstrations by the members of the deparment of chemistry of Western Illinois State Teachers College, and also the industrial trip planned for the morning. These features have been arranged by Mr. Ralph Waldo Horrabin of the faculty of Western Illinois State Teachers College.

The luncheon also should not be overlooked as a means of getting together, getting acquainted, and meeting the chemistry teachers of the western part of Illinois.

Some Objectives of the I. A. C. T.

Illinois State Normal University HOWARD W. ADAMS Normal, Illinois

To one conversant with present day social and industrial trends, it is obvious that there should be more elementary chemical instruction and, consequently, more teachers. Chemical science is basic to great social and industrial changes and the future citizens of the commonwealth should today be receiving more instruction in this knowledge. Such fundamental social movements as improvements in public health and the control of human and animal diseases must rest, ultimately, upon a widespread diffusion of chemical and allied knowledge. It is not enough that there be skilled research workers in such fields. To make the results of their discoveries avaliable and useful to the many, there must be general intelligence. Conservation of soil fertility and the production and processing of foods again require widespread intelligence of which chemical knowledge is an important factor. The delay in obtaining desirable legislation pertaining to foods, drugs, and cosmetics is largely due to lack of insistence on the part of the general public and the forthcoming Copeland bill will contain such compromises as the lack of public interest and intelligence will permit. Chemical science is revolutionizing industrial production. Moreover, an industry, new in American industrial life, has arisen during the past twenty years which has forged ahead despite the depression. This new development is the chemical industry.

In the second place, chemical science, offers unusual opportunity for training in reflective thought of a pattern which fits admirably into the thought processes required in our modern life. To say that we live in a scientific age cannot be denied, but to maintain that the age demands of us scientific thinking is not so frequently recognized. People are inclined to try to couple 18th century thought habits with 19th century living, only to find that they are bewildered. Chemical instruction, through individual laboratory work, offers unparalleled opportunity for such training. So the second objective of the Association is the extension of this kind of educational opportunity. We believe there is no educational device which does this so well as instruction in this science, especially when coupled with adequately conducted laboratory work. Here, we believe, is an aid to a liberalizing education which is worthy of more extensive use in both our secondary and higher institutions. Too often chemical instruction has been considered as useful only to the would-be specialist, whereas, it has in it unusual broad educational values.

In the third place, as chemistry teachers, we need closer co-operation and association if the above mentioned values are to be conserved and extended. Chemical instruction, secondary, and collegiate, did not find a place in the curriculum except by intelligent and sustained effort on the part of its advocates. It will not be retained nor advanced to keep pace with changing social and industrial conditions without our united effort. To facilitate this mutually helpful association, we have two meetings yearly for exchange of ideas and for inspiration. Moreover, there is a journal, The Illinois Chemistry Teacher, ably edited and managed by Mr. John C. Chiddix of Normal. This journal, now in its third year, finds its way, we hope, into the hands of a majority of the teachers of secondary and collegiate chemistry in the state. It is our own journal and is in no sense a competitor of the Journal of Chemical Education, the able publication of the Division of Chemical Education of the American Chemical Society edited by Dr. Reinmuth.

This, then, as the writer sees it, is the immediate three-fold purpose of the Illinois Association of Chemistry Teachers: to extend in both secondary and higher institutions, instruction in Chemical science, to preserve and extend that unique kind of educational opportunity which the science offers, especially when accompanied by properly directed laboratory work, and to co-operate as teachers in attaining these desirable ends.

Non Aqueous Solvents

L. F. AUDRIETH

University of Illinois Urbana, Illinois

Among the most notable advances in the field of experimental chemistry in the last thirty years is the increased use of solvents other than water as media for carrying out chemical reactions. Water is by no means a distinctive solvent, even though it is the most widely distributed and the most readily available one. Many other compounds exhibit marked and exceptional solvent character. Many pure compounds may serve as ionizing media. Hundreds, yes thousands of compounds may coordinate with typical inorganic salts to form solvates (compounds with solvent of crystallization) analogous to hydrates. However, none of these non-aqueous solvents has been the subject of quite as much study and investigation as liquid ammonia, a substance which, surprisingly enough, is the most water-like material known outside of water itself.

Anhydrous ammonia is now manufactured in tremendous tonnages. It is shipped in tank car lots and can be purchased in cylinders of various sizes at a cost varying from 30c to 15c per pound depending upon the quantity. One pound of ammonia occupies a volume of 747 cc. at room temperature. Consequently it is one of the cheapest of the chemically pure, anhydrous solvents. It is no wonder, therefore, that it has found application in industry for many purposes. The patent literature gives ample evidence of its technical uses.

Ammonia boils at —33.5°. Its heat of vaporization (337 calories per gram) is higher than that of any other substance with the exception of water. In physical properties, it does not fall in line with the other hydrides of the fifth group of the periodic table. In this respect it resembles water and hydrogen fluoride, both of which occupy anomalous positions compared with the hydrides of their respective groups. Ammonia, like water and hydrogen fluoride, is an associated liquid. It does not exist in the form of single molecules, but is made up of more complex molecular units.

SOLVENT PROPERTIES OF AMMONIA

Ammonia possesses remarkable solvent properties. It is not as good a solvent for inorganic compounds as water, but excels the latter in its ability to take into solution organic compounds. Many of the salts of nitrogen containing acids, such as the nitrates, nitrites, thiocyanates, cyanides and cyanates are quite soluble. Salts of the oxyacids, such as the carbonates, phosphates, sulfates, sulfites, etc. are generally insoluble. The silver halides are fairly soluble and this solubility decreases in the following order: AgI AgBr AgC1. Iodides are usually more soluble in non-aqueous solvents than the chlorides.

Most surprising is the fact that the alkali and alkaline earth metals are soluble in liquid ammonia. All of them dissolve to give blue to bronze colored solutions, depending upon the concentration. As evidenced from the date in Table 1 these solubilities are truly remarkable when one considers that only 11.1 g. of sodium sulfate dissolve in 100 g. of water at 18°

TABLE 1

Solubility of Metals in Liquid Ammonia at —33.

Lithium	11.3	0.28
Sodium	24.6	0.18
Potassium	49.0	0.21

Solutions of sodium in liquid ammonia are stable for months. Upon exaporation of the solvent the metal is recovered in its original form. As might be expected solutions of the alkali and alkaline earth metals in liquid ammonia are powerful reducing agents.

Many inorganic compounds are deliquescent in an atmosphere of ammonia. Even at room temperature ammonium nitrate and ammonium thiocyanate absorb sufficiently large quantities of ammonia so that the resulting products become liquid. In other words the vapor

pressure of ammonia can be reduced to such an extent by the addition of these salts that the resulting solutions are stable at room temperature.

It has already been pointed out that ammonia readily dissolves many organic compounds. Such hydrocarbons as hexane and benzene are readily soluble. Organic halogen derivatives are generally soluble, but if the particular halide under investigation is not soluble enough more of it can be made to go into solution by simply adding some such organic compounds as ether or benzene. One might expect organic nitrogen compounds to be quite soluble and experimental observation has substantiated this suposition. The amines, acid amides and imides, amidines, hydrazines, nitrocompounds, etc., seem to exhibit preferential solubility in liquid ammonia. The author has emphasized repeatedly that ammonia is the logical solvent for the study and preparation of nitrogen compounds, both organic and inorganic.

The Nitrogen System of Compounds

Before discussing reactions in liquid ammonia it might be well to point out that there exists between ammonia and many nitrogen compounds a relationship which is quite similar to that which obtains between water and the usual oxygen compounds. We may hertefore consider cerain groups derived from ammonia as quite analogous to the corresponding groupings found in typical **aquo**-compounds. The analogous nitrogen compounds may be called **ammono**-derivatives.

H_2O	$OH-$	$O=$	
H_2S	$SH-$	$S=$	
HNH_2	NH_2-	$NH=$	$N=$

Certainly no one will deny that sulfur may replace oxygen with formation of thio-compounds. The fact that nitrogen is trivalent means that there are just that many more possible nitrogen analogs of known oxygen compounds.

Suppose we replace the hydrogen of ammonia by a metallic atom such as potassium. The resulting compound, KNH_2, potassium amide, is formally related to ammonia as potassium hydroxide is to water as the parent substance. Mercuric nitride is the analog of mercuric oxide. Chloramine is an ammono-hypochlorous acid. Urea is sort of a half water, half ammonia derivative of carbonic acid. Cyanamide may be regarded as the ammonia analog of carbonic acid. Acetamide and acetamidine could be looked upon as the acetic acid derivatives of the ammonia system of compounds. We could go on indefinitely and point out any number of formal relationships of this type. A few are reproduced in Table **II.**

TABLE II

Aquo-and Ammono-Compounds

Aquo-compound	Ammono-compound	Name
KOH	KNH_2	potassium amide
PbO	$PbNH$	lead imide
$2HgO$	Hg_3N_2	mercuric nitride
$HOCl$	H_2NCl	chloramine
$CO(OH)_2$	$CO(NH_2)_2$	urea
	$CNNH_2$	cyanamide
CH_3COOH	CH_3CONH_2	acetamide
	$CH_3C(NH)NH_2$	acetamidine
C_2H_5OH	$C_2H_5NH_2$	ethvlamine
C_6H_5OH	$C_6H_5NH_2$	aniline
$(C_2H_5)_2O$	$(C_2H_5)_3N$	triethylamine

However, analogies of this sort are of no particular importance unless they lead to new and useful applications. Does potassium amide really act as a base in liquid ammonia? Is urea an acid and does it form salts? Is it proper to consider acetamide as an ammono-acid, even if we have been taught to look upon it as a basic substance? In other words, does solution of many of these compounds in liquid ammonia cause them to exhibit the characteristics which have been deduced for them formally as ammono-derivatives? Does experimenal fact substantiate what might otherwise be considered a fanciful flight into the realms of imaginative chemistry? The answer to all of these questions is emphatically and decisively **Yes.** A consideration of a series of typical reactions in liquid ammonia will serve to make clear the logicality of the concept of an ammonia sysem of compounds.

Reactions of Liquid Ammonia

Solutions of metallic potassium in liquid ammonia are fairly stable, but reaction between solvent and solute can

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NUCLEAR PHYSICS

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is one very important characteristic of all these processes, however, which must be emphasized. No kind of chemical experiments performed with radioactive elements has any influence on the rates at which these radioactive elements decompose. If one were to isolate a gram of radium metal, for instance, it is known that in about 1700 years only a half gram of radium would remain. Exactly the same thing would happen to the radium if it were compounded with chlorine in the form of radium chlorid. Also no physical experiment seemed at first to have any influence on this rate. For instance, holding the radium at liquid air or furnace temperatures in no way changed the rate. We now think we know how it could be done but the experiment has yet to be performed in the laboratory.

But the radioactive processes are known to involve transformations in the nuclei of the atoms. The fact that the atoms consist of nuclei with a swarm of planetary electrons has been demonstrated by a study of the processes themselves. Using x-rays as a tool, Moseley also discovered something of prime importance about the chemical elements, namely, that each element may be characterized by a number which will be more descriptive of its chemical properties than its atomic weight. These numbers are known to represent the number of planetary electrons in each atom and the chemical properties are known to be due to a few of the electrons in the outside of this swarm.

Now at once we are struck by the possibility of transmuting the elements if we could only change the charge (not the mass) of the nucleus of an atom so that the number of planetary electrons which this nucleus will retain will change. If this can be done the ancient problem of the alchemist will be solved. We have, in fact, restated the problem. Careful study of the elements which exist has indeed shown that many of the chemically unique elements are mixtures of atoms having the same atomic number but different mass or atomic weight. Tin, for instance, consists of no less than eleven kinds of atoms each one differing from the other in mass but all having the same number of planetary electrons and hence identical chemical properties. The nuclei only being different. Reference to a table of known isotopes shows that nearly all of the elements have two or more isotopes and the symmetries in their arrangement argues clearly for the point of view of the alchemists; namely, that all matter consists in atomic structures built from common elementary parts.

Of these elementary parts there are now known several. Whether these will submit to further division is not known. To recount the history of their discovery and to argue for their reality is beyond the scope of this discussion. Most of them have been discovered, and practically all we know of them determined by experiments performed in the last few years. A list of those about whose existence there can be little doubt would include the electron and position (negative and positive charges of electricity) with a mass of 0.00055 units on the basis of an oxygen atom being 16. Besides these are known as elementary particles the proton and neutron. Though strangely alike in mass they are very different in properties since the proton has the same mass as a hydrogen ion and the same charge. The neutron on the other hand has an almost identical mass but no charge at all and when in motion passes through thick layers of lead as if nothing were there. A proton and one planetary electron can be identified as a hydrogen atom. A proton and a neutron combined form a nucleus whose atomic weight is almost the same as the molecular weight of hydrogen but such a combination is not at all like the diatomic molecule of hydrogen. In fact, it is much more like the **atom** of hydrogen except that its mass is twice as great. It is actually the heavy isotope of hydrogen which combined chemically with oxygen forms the recently discovered heavy water. To distinguish the nucleus of this heavy hydrogen from the proton it is called the deuteron. The deuteron plus its planetary electron is the one isotope in the per-

iodic table which has merited a special name. Heavy hydrogen is called deuterium.

The existence of these elementary particles has been demonstrated largely by studying natural radioactive processes. Nuclei are known to be about 10^{-13} cm in diameter. The planetary electrons range in a volume about 100,000 times as large. In radioactive disintegration these electrons are not involved. The disintegration occurs rather when beta-rays (highs peed electrons) are ejected from the nuclei of parent atoms. Disintegrations are also known where alpha-rays are ejected, the alpha-rays bring nothing else than helium nuclei traveling at speeds of perhaps a tenth that of light and carrying a double positive charge, i. e. doubly ionized helium or helium nuclei stripped of all planetary electrons. This last was demonstrated by Rutherford and Soddy about 1904. When beta and alpha-rays are ejected they are often accompanied by gamma-rays which are similar to X-rays and are wave bundles of energy of much higher frequency but otherwise like ordinary light.

Using the alpha-particles given off by a radio-active source Rutherford in 1919 first performed an experiment which changed the charge on a nucleus. He succeeded in knocking protons out of nitrogen nuclei. We know now that the nuclear reactions may be written

$$2He^{4} + 7N^{14} \rightleftarrows 8O^{17} + 1H^{1} + E.$$

A word of explanation must be given. The analogy with chemical equations is evident. The subscripts represent atomic numbers and hence net positive charge on the nuclei involved. Conservation of electric charge demands that the sum of the subscripts on both sides of the equation must balance. The law of conservation of mass, however, does not hold exactly as the atomic weights are in no case exact integers with the exception of course of ${}_8O^{16}$ which is arbitrarily set at 16. Hence, it is necesary to add E an amount of energy to one side of the above equation to take care of the amount of mass which may be transformed into energy by the reaction or vice versus, this transformation following the Einstein law $E = MC^2$ where M is the mass transformed, E the energy and C^2 the square of the velocity of light.

The actual impact between the nucleus of the nitrogen atom and alpha-particle results in the capture of the alpha-particle hence the **kinetic** energy of the incident particle will not be conserved, the collision being inelastic. But the momentum will be conserved and from measurements of the velocities of the incident alpha-particles and that of the ejected protons the value of E can be computed and the truth of the nuclear reaction demonstrated.

Since 1919 many such experiments have been performed. Recently also artificial means have been developed for speeding up protons, deutrons, and alpha-particles.

Many chemical elements bombarded by these particles have been shown to form new isotopes. Some of these isotopes are radioactive and have never before existed on this earth at least for millions of years. Notable among these is radioactive sodium of atomic number eleven but atomic weight 24 instead. Its chemical properties are identical with ordinary sodium and it changes into this kind in short time ejecting an excess neutron. A few typical nuclear reactions among the lighter elements are

$$4Be^{9} + 1H^{1} \rightleftarrows 3Li^{6} + 2He^{4} + E$$
$$4Be^{9} + 1H^{2} \rightleftarrows 3Li^{7} + 2He^{4} + E$$
$$4Be^{9} + 1H^{2} \rightleftarrows 3Li^{6} + 2He^{5} + E'$$
$$1H^{2} + 1H^{2} \rightleftarrows 2He^{3} + oN^{1} + E$$
$$1H^{3} + 1H^{1} + E'$$
$$5B^{11} + 1H^{1} \rightleftarrows 32He^{4} + E$$

One symbol occurs in one of the above equations which has only been named, that is ${}_0N^1$. This represents the neutron whose atomic number is zero and whose mass is very nearly that of the proton. Discovered very recently by Chadwick its properties are so unique and its value as an experimental tool so great that its story cannot be told with any justice here. It is worthy of note that its discoverer has recently been awarded the Nobel prize. Many other such reactions as those above are known. That it will be possible to realize the ancient dream of the alchemist by such processes remains to be seen. Certainly the type of experiment needed is not known.

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PROGRAM OF SPRING MEETING
of
ILLINOIS ASSOCIATION OF CHEMISTRY TEACHERS

Western Illinois State Teachers College, Macomb, Illinois

Saturday, March 28, 1936

10:00 A. M. Industrial Excursion, Illinois Electric Porcelain Company. Start from Hotel Lamoine.

12:15 Noon. Luncheon. Hotel Lamoine. Cost 50 cents. Send reservations early to H. Waldo Horrabin, Western Illinois State Teachers College, Macomb, Illinois.

1:15 P. M. Excursion through Western Campus.

1:40 P. M. Convene for afternoon meeting in chemistry lecture room.

Greetings: President Morgan, Western Illinois State Teachers College.

Business session. Election of officers.

Round Table Discussion. Problem: The Class Demonstration vs. Laboratory Work in High School Chemistry. Led by J. H. Sammis, Peoria Central High School, Everett S. Anderson, Quincy Senior High School, Carl E. Ekblad, Moline Senior High School, Joseph D. Dixson, Monmouth High School, George E. Baird, Rock Island High School.

General Discussion.

Adjournment.

Dues—you may become an active member of the Illinois Association of Chemistry Teachers by sending your 50 cents to the Secretary-Treasurer, Mr. S. A. Chester, Bloomington High School, Bloomington, Illinois. It is easier to mail one dollar and pay your dues for two years as several are now doing. BE AN ACTIVE MEMBER.

CHEMISTRY WORK BOOK by Charles E. Dull

Henry Holt & Company, Chicago

The CHEMISTRY WORK BOOK by Chas. E. Dull is organized on the unit basis and follows the general plan of approach to subject matter characteristic of most chemistry texts for secondary schools. It differs from many work books in giving more attention to the interchange of electrons as the basis of chemical reaction and as a means of interpreting valence than is usually given, a feature that satisfies the student's desire to kno wwhy elements react as they do. Acids, base and salts are treated together in one unit. Included in the introductory unit is a study of the units of weights and measurements used in chemistry. The story of organic chemistry has been paced last for the convenience of the teacher.

Each unit is introduced by an overview and also a set of self-directing or study questions that help the student to grasp what the work is about. Exercises on the material of the text and also laboratory experiments with blanks to be filled in are included. The exercises involve mostly the filling of blanks. Each exercise is divided into an A and B section. The latter serves the needs of the brighter students. The exercises can be worked even before the experiments have been performed. Self-examining tests are also included for student practice in preparation for the regular tests which are provided in separate booklets for the convenience of the teacher.

In using the work book it will be found advantageous to have a few copies of **Dull's Modern Chemistry** available for reference for the students.

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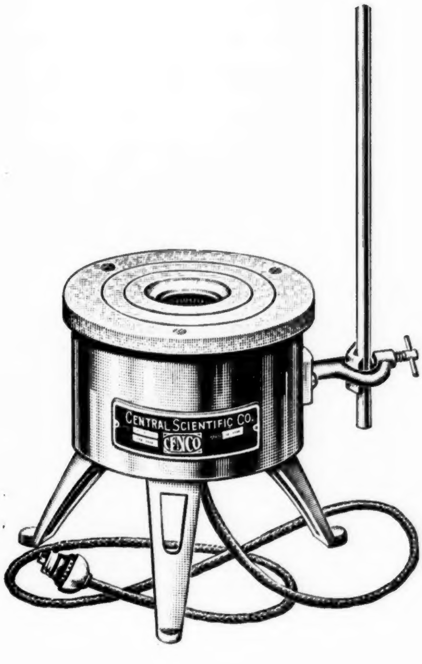

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NON-AQUEOUS SOLVENTS

(Continued from page five)

be catalyzed by various substances such as finely divided iron or platinum. Soluble potassium amide is formed and hydrogen gas is evolved (Equation 1). If phenolphthalein is now added, the solution assumes

1. $K + NH_3 = KNH_2 + \frac{1}{2}H_2$
   . $K + H_2O = KOH + \frac{1}{2}H_2$

a pink color. If now ammonium chloride (All ammonium salts behave as acids in liquid ammonia) is added in proper quantity the pink color is discharged and some potassium chloride is precipitated,

2. $KNH_2 + NH_3.HCl = KCl + 2NH_3$
   $KOH + H_2O.HCl = KCl + 2H_2O$

Potassium amide and mercuric nitrate react in liquid ammonia with the precipitation of mercuric nitride (3). Curiously enough, mercuric amide appears to be no more capable of existence than the corresponding hydroxide.

3. $6KNH_2 + 3Hg(NO_3)_2 = Hg_3N_2 + 6KNO_3 + 4NH_3$
   $2KOH + Hg(NO_3)_2 = HgO + 2KNO_3 + H_2O$

Zinc nitrate and potassium amide react first to give a precipitate of zinc amide which dissolves in the presence of an excess of the ammono-base. Zinc amide is an amphoteric amide (4).

4. $Zn(NH_2)_2 + 2KNH_2 = K_2Zn(NH)_2.2NH_3$
   $Zn(OH)_2 + 2KOH = K_2ZnO_2.XH_2O$

Suppose urea is added to a solution of sodium in liquid ammonia. The blue color is discharged, hydrogen gas is evolved and a precipitate of disodium urea is formed (5). The mono-sodium salt of acetamide is formed in the same way (6). Both urea and actamide behave as acids in liquid ammonia.

5. $CO(NH_2)_2 + 2Na = CO(NHNa)_2 + H_2$
6. $CH_3CONH_3 + Na = CH_3CONHNa + \frac{1}{2}H_2$

Ammonia also behaves as a solvolytic agent. Just as water hydrolyzes phosphorus trichloride, so ammonia effects its ammonolysis (7). Many non-metallic halides are ammonolyzed in the same manner.

7. $PCl_3 + 5NH_3 = P(NH)NH_2 + 3NH_4Cl$
   $PCl_3 + 3H_2O = P(OH)_3 + 3HCl$

Ammonobasic salts are also known. Addition of mercuric chloride to ammonia results in the formation of mercury amidochloride (or ammonobasic mercuric chloride). The addition of ammonium chloride (an ammono-acid) causes the precipitate to go into solution. (8) This reaction reminds one of the behavior of antimony chloride towards water.

8. $HgCl_2 + 2NH_3 = HgNH_2Cl + NH_4Cl$
   $SbCl_3 + H_2O = SbOCl + 2HCl$

Solutions of sodium in liquid ammonia have some extremely interesting properties. The addition of silver nitrate results in the precipitation of finely divided metallic silver (9). With zinc cyanide an intermetallic compound, $NaZn_4$, is precipitated. (10). If sulfur is added white sodium sulfide is precipitated. An excess of sulfur causes the sulfide to go into solution with formation of a polysulfide. (11). Polyselenides, polyarsenides, and even polyplumbides and polystannides—all of them soluble in liquid ammonia—have been prepared in this fashion.

9. $AgNO_3 + Na = Ag + NaNO_3$
10. $4Zn(CN)_2 + 9Na = NaZn_4 + 8NaCN$
11. $2Na + S = Na_2S$
    $Na_2 + xS = Na_2Sx$

Sodium solutions are excellent reducing agents and have considerable application in organic chemistry. Nitrobenzene can be reduced, step by step, to aniline. Halogen can be removed quantitatively from organic compounds as the sodium halide. Alkylations can be carried out very effectively in liquid ammonia. It should be remembered that alkyl halides are quite soluble. Sodium derivatives of various compounds can be made easily by the direct action of the substance upon solutions of sodium in liquid ammonia. An example will make the usefulness of this method clear. Suppose it is desired to prepare ethylaniline, $C_6H_5NHC_2H_5$. Aniline is added to a solution of sodium in liquid ammonia until the characteristic blue color has been discharged. The solution now contains mono-sodium anilide, C_6H_5NHNa. The proper amount of ethyl iodide is then added to the solution and the ammonia is allowed to evaporate. The residue, consisting of ethyl aniline and sodium iodide is extracted with ether, leaving behind the latter. A similar procedure has been employed for the

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Whether it will be a practical experiment or not is doubtful.

Knowledge of these nuclear reactions has led to new and better determinations of atomic weights. Those of some of the lighter elements are

Element		
$_0N^1$ (Neutron)	—	1.0083±0.0003
$_1H^1$ (hydrogen)	—	1.0081±0.0001
$_1H^2$ (deuterium)	—	2.0142±0.0002
$_2He^4$ (helium)	—	4.0034±0.0004
$_3Li^6$ (Lithium light isotope)	—	6.0163±0.0006
$_3Li^7$ (Lithium heavy isotope)	—	7.0170±0.0007
$_4Be^9$ (beryllium)	—	9.0138±0.0005
$_5B^{10}$ (boron light isotope)	—	10.0143±0.0003
$_5B^{11}$ (boron heavy isotope)	—	11.0110±0.0003
$_6C^{12}$ (carbon)	—	12.0027±0.0003

One further phenomenon in nuclear physics deserves special attention. We note that deuterium is formed by combining a neutron and a proton. This should give the atomic weight of deuterium as 1.0083 + 1.0081 = 2.0164. But as measured the atomic weight of deuterium is 2.0142. Hence in forming deuterium a mass of .0022 mass units has to be transformed into energy. This means that deuterium is quite stable and an equivalent energy would have to be supplied to an atom of deuterium all at once to make the reaction go in the opposite direction forming a neutron and a proton. This energy is the same as the energy acquired by an electron falling down a potential hill of some two million volts. Now an electron falling down a potential hill of about one volt would have as much energy as is liberated when an atom of oxygen and carbon combine forming carbon monoxide. The energies involved in the formation of deuterium are a million times as large. If carbon monoxide is heated to 2500° K, the temperature of the explosion in a gasoline engine, the collisions become so violent that many of the carbon and oxygen atoms are knocked apart.

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preparation of mixed ethers, thio-ethers, N-alkylated acid amides, disubstituted asymmetric hydrazines, etc.

Ammonia As An Electrolytic Solvent

It has already been pointed out that ionic reactions take place in liquid ammonia. In fact ammonia is an excellent ionizing solvent and solutions of salts in liquid ammonia conduct the electric current with facility. What is most unusual is that many substances, ordinarily considered non-electrolytes as based on their behavior in aqueous solution, become electrolytes in liquid ammonia. Many organic compounds exhibit marked conductance.

Even solutions of the alkali and alkaline earth metals conduct the electric current. In concentrated solution the conductance values are tremendously high and it is believed that the conduction process is metallic in character. In dilute solution conduction is ionic. Solutions of these metals in liquid ammonia therefore furnish the link between metallic and electrolyic conduction.

Electrolysis of solutions of metallic salts in liquid ammonia permits of the cathodic discharge of various metals. The author has been able to plate out many of the commoner metals, such as nickel, tin, lead, copper, mercury, antimony, etc., from solutions of their salts in liquid ammonia. Even beryllium can be discharged from liqui dammonia solutions containing beryllium nitrate and ammonium nitrate. If a solution of sodium iodide is electrolyzed the blue color of sodium forms around the cathode. If a solution of tetramethylammonium iodide is electrolyzed a similar blue color develops indicating tha free tetramethylammonium is probably formed.

Conclusion.

Let us imagine a world in which nitrogen and ammonia have replaced oxygen and water. Not such a fanciful flight of the imagination as we might first think—for astronomers have demon-

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strated that the gaseous envelope surrounding at least one of the planets conains considerable ammonia. What a world and what a life! The process of combustion would involve nitridation—and the chemical inertness of nitrogen would require opportunity for the development of high temperatures if it were to replace oxygen. But very low temperatures would also be necessary in such a world. Our seas, rivers and lakes would be made of liquid ammonia if we assume atmospheric pressure to be equal to 760 mm. of Hg on such a planet. The temperature could not rise above —33.5 or our bodies of ammonia would disappear. To have a snowfall of solid ammonia it would be necessary for the temperature to drop below —77 degrees. If the temperature dropped below —77 degrees for any length of time, however, all bodies of liquid ammonia would freeze solid. Solid ammonia does not float in the liquid. At least, it would not be necessary to worry about ammonia icebergs! Limestone would be replaced by calcium cyanamide, the ammonia analog of calcium carbonate and quartz, by silicon nitride. Our alcoholic beverages would contain ethylamine instead of ethyl alcohol. Imagine washing our hands in liquid ammonia and using the sodium salt of palmitamide as soap.

Idle and fanciful as speculation of this sort may seem and grotesque as the results appear to be, it illustrates how analogy may serve a useful or a useless scientific purpose. The nitrogen system of compounds was evolved as a result of reasoning by analogy. Theoretical considerations concerning ammonia and ammono-compounds have not only served to coordinate and classify existing knowledge and fact, but have pointed the way to new problems.